5. ANALYSIS

The following section includes a series of maps generated from the GIS Communications Infrastructure database, which was developed specifically for this project. Each map has been generated individually to analyze specific issues such as high utilization segments in a region and to look for other opportunities, such as utilizing existing fiber optic routes or microwave paths to augment or replace leased line connections. Each analysis map is discussed in detail below.

It is important to note that the data for this GIS database has come from numerous sources. Therefore the level of accuracy is for planning purposes only and some discrepancies may be noted, particularly between sites, microwave shots and fiber locations.

5.1 INTER-REGIONAL COMMUNICATIONS

Figure 28 is the first of two Inter-regional Analysis maps. The figure is focused on high utilization segments, as discussed in Section 3.1 (and summarized in Figure 6). As illustrated in Figure 28, only the Olympia to Wenatchee HQ T1 connection is currently operating over 20% utilization. However, the Olympia to Yakima HQ, Olympia to Spokane HQ, and Olympia to Tumwater HQ connections are all currently operating near the 20% threshold.

Figure 28 also displays some possible microwave routes that may be utilized to either augment (and bring redundancy) or replace (to minimize operational cost) the leased line connections between the Olympia HQ and each of the regional HQ offices. As this figure illustrates, several microwave segments (or "shots") would have to be upgraded to complete the connection between Olympia and each regional HQ.

Further analysis should be completed to compare the estimated cost of upgrading each of these microwave paths, as compared to on-going leased line connections.

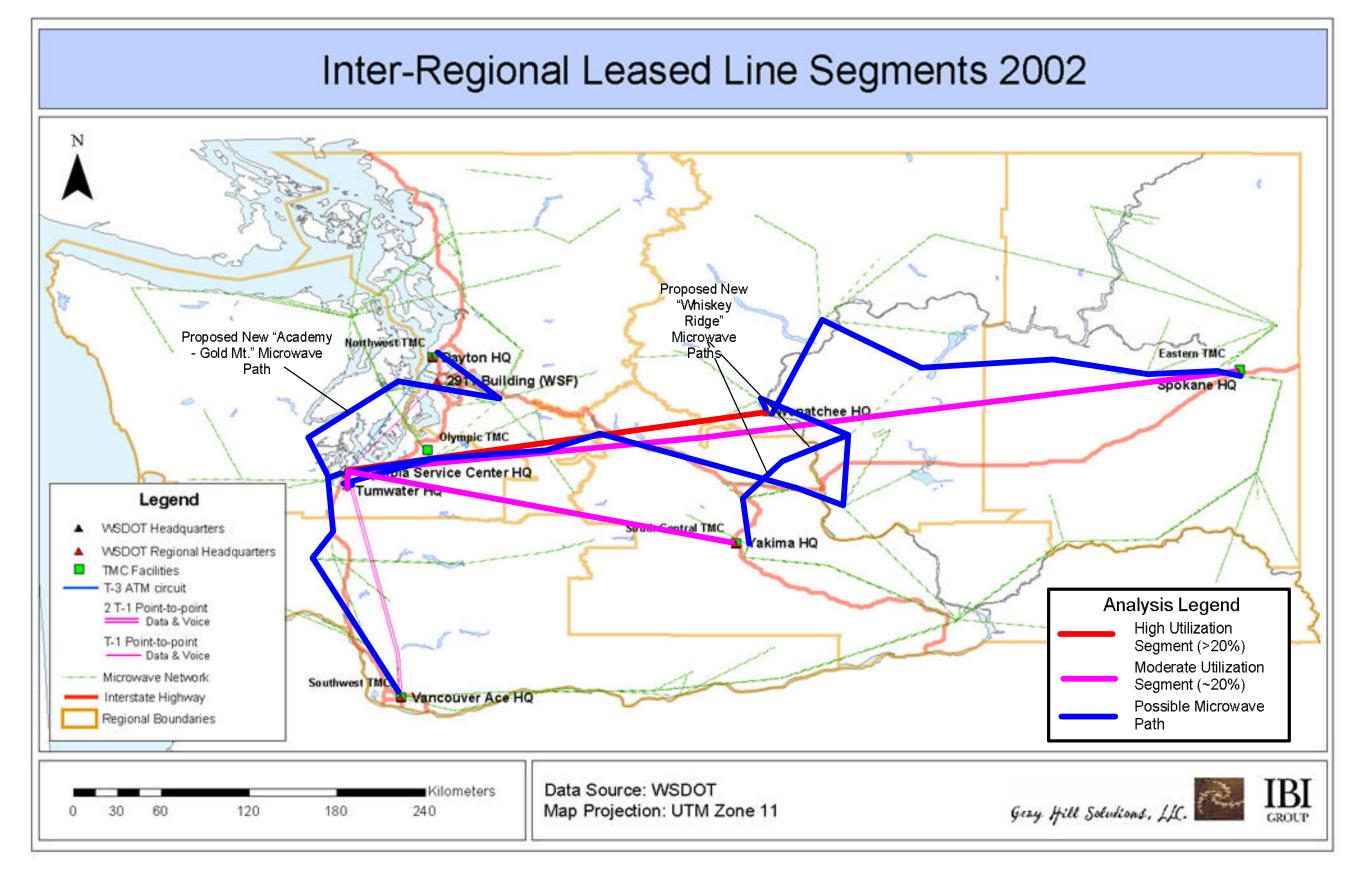


Figure 28: Inter-regional Analysis - Bandwidth Utilization

Figure 29 is the second of the Inter-regional Analysis maps. This figure is focused on Inter-regional ITS Communications Requirements. This schematic reflects the discussion from Section 3.1.2.2 on ITS Center-to-Center (C2C), and puts this discussion into a geographic context. As discussed previously, several of the regions had indicated interest in being able to share video and data, or in some cases data only¹⁵, with a neighboring region. This requirement will become more prevalent as more field devices are deployed, particularly along regional boundaries. The specific C2C requirements illustrated in this figure include the following:

- Vancouver TMC to Olympic TMC: Video and Data
- Olympic TMC to Dayton (NW) TMC: Video and Data
- Dayton TMC to Bellingham TMC: Video and Data
- Wenatchee HQ to South Central TMC: Video and Data
- Eastern TMC to South Central TMC: Data Only
- South Central TMC to Dayton TMC: Data Only

The requirements should be confirmed before detailing planning for these inter-regional Center-to-center connection is begun. However, the analysis illustrates that point-to-point connections between the WSDOT regional TMC do not currently exist. Instead, several segments of the network are utilized (and all routed through Olympia) to send data or video between two neighboring TMCs.

Also illustrated in Figure 29 are the possible microwave routes that may be utilized to support these ITS C2C requirements. Since many of the TMCs are collocated with the regional HQs, several of these microwave paths are identical to the paths identified in Figure 28. When this is the case, it might be said that an upgrade of the microwave path is required to support both ITS and Enterprise/IT requirements.

A few of the microwave paths identified in both Figure 28 and Figure 29 do not currently exist in the WSP/WSDOT network. These paths have, however, been identified as future microwave shots by WSP/WSDOT in their documentation of the network, and have been labeled on the figures.

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¹⁵ "Data only" may include access to and/or control of VMS, HAR, RWIS and other field devices. Video accessed from the WSDOT website is considered sufficient for these connections.

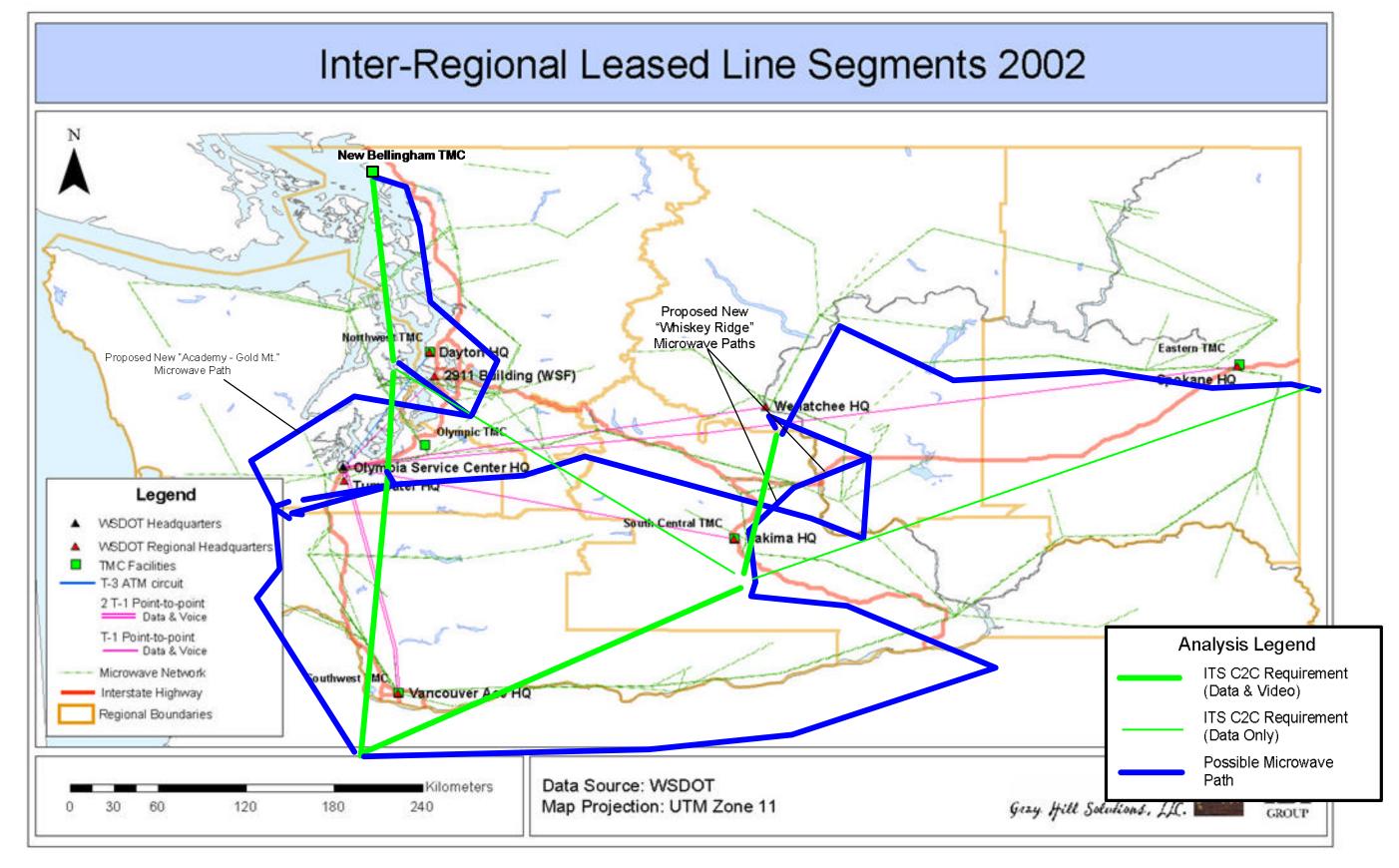


Figure 29: Inter-regional Analysis - ITS Center-to-Center (C2C) Requirements

5.2 INTRA-REGIONAL COMMUNICATIONS

This section includes a series of analysis maps focused on each individual WSDOT region. The high utilization segments are identified, as discussed in Section 3.2 and summarized in

Figure 16. In addition to the leased line connections, alternate communications options are highlighted in each of the maps including possible microwave and/or fiber routes.

As discussed in Section 3.2, many of these regional sites share Frame Relay T1s (referred to as frame relay clusters in this document.) Often times, one or more of the sites in the Frame Relay "cluster" are much larger than the other sites or at least have higher bandwidth requirements, due to the nature of the facility. If one of the sites in the "cluster" is such a high bandwidth user that it causes a network slowdown, the other sites will experience the slowdown as well. The purpose of identifying the individual high bandwidth segment is to indicate which leased line segments would bring the biggest benefit if upgraded or replaced by either microwave or fiber connections.

Figure 30 illustrates the leased line connections in the Northwest Region, highlighting the high bandwidth connections, possible microwave routes and fiber optic routes. As indicated in this map, there are three Frame Relay clusters that are considered high bandwidth users (i.e., exceed 20% utilization). Also indicated in the map are the individual segments within each cluster, which are the highest bandwidth users. (Note that the routing of the frame relay clusters was estimated in all of these maps, based on an assumption of the location of the telco hub that connects the members of the cluster.) The map indicates that only two of the high utilization sites (Bellingham and Mt. Vernon) appear to be directly on the microwave routes. In other words, none of the other sites could even take advantage of microwave as a communications medium, unless new microwave paths were specifically constructed.

There are, however, several sites that are either directly on or very near the existing fiber optic ring that WSDOT owns and maintains. In fact, three of the sites (Survey, Roanoke and Mercer) are already utilizing the fiber backbone for communications back to Dayton. As discussed in Section 3.2.4, WSDOT IT is currently working together with the Advanced Technologies (ITS group) to identify opportunities to migrate the Everett Satellite site (known internally as El Capitan) to a fiber connection. The intention would then be to change the frame relay cluster currently connecting Everett North to Mt. Vernon, Burlington, Stanwood and Bow Hill, and instead have this cluster be connected to El Capitan. With the fiber backbone from El Capitan to Dayton in place, this would free up bandwidth for all sites that are currently sharing this cluster.

Other opportunities may include working with the cities of Seattle, Bellevue and Redmond to utilize their fiber optic networks to connect to the various sites located within each city. These cities may be able to provide "last mile" connectivity between WSDOT's fiber network and the various sites. This could be particularly beneficial in Seattle, where WSDOT has over 10 different facilities.

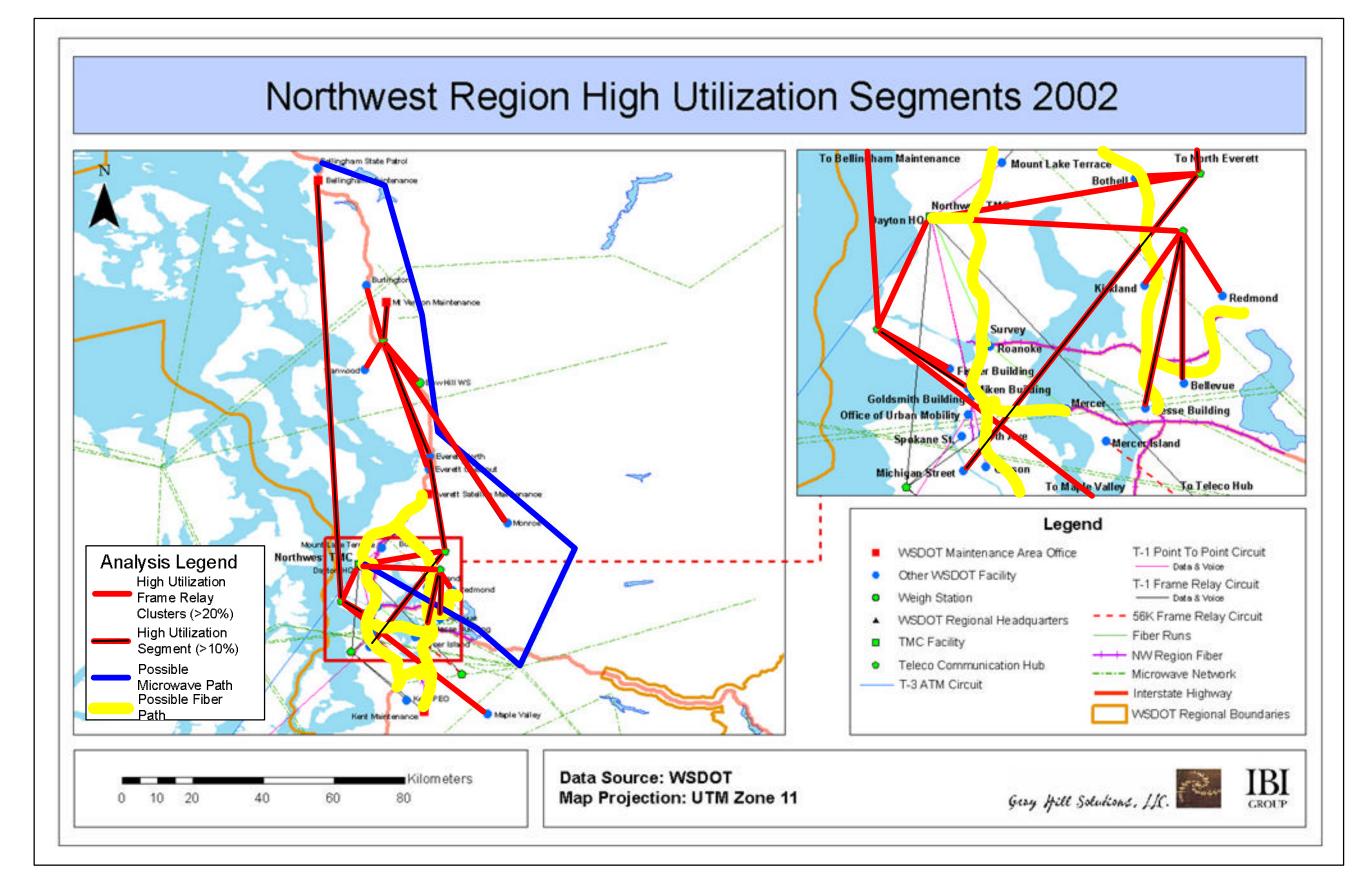


Figure 30: Northwest Region Analysis Map

Figure 31 illustrates the Olympic Region's leased line segments, high bandwidth Frame Relay clusters and microwave paths. As indicated in this map, two of the Frame Relay clusters are currently high bandwidth utilization groups. In this case, two of the highest bandwidth sites (Port Angeles Maintenance and Port Orchard—one in each cluster) appear to be directly on microwave paths. Other, smaller sites (particularly Aberdeen Maintenance and Elma) also appear to be able to be fed via microwave. However little benefit would be gained as compared to the cost of upgrade.

Figure 32 illustrates the Southwest Region's leased line segments, possible microwave paths and fiber optic plant. In this region, none of the leased line segments or Frame Relay clusters is currently operating at over 20% utilization; therefore none are indicated as high bandwidth utilization segments. However, this is partly because Kelso and Vancouver Maintenance (two of the larger sites) are currently using two dedicated T1 connections, triggering even higher ongoing operational costs. As indicated in the map, the Kelso site may be able to utilize microwave to connect back to the Vancouver HQ. The Vancouver maintenance site however, is not on an existing microwave path. The map indicates that the Vancouver Maintenance site may be located near the future fiber planned for construction along I-205. WSDOT should consider designing this new fiber to connect Vancouver Maintenance back to the regional HQ.

Figure 33 illustrates the South Central Region's leased line segments and possible microwave paths. In this region, none of the leased line segments or Frame Relay clusters is currently operating at over 20% utilization. Possible microwave paths are indicated on the map to show potential connectivity between the Yakima HQ and the field offices, and there appear to be opportunities to use microwave to contact the majority of the offices in the region. However, since none of the segments are running near capacity, the benefit of upgrading the microwave network in this region may be lower than the others.

Figure 34 illustrates the Eastern Region leased line segments, high bandwidth utilization frame relay cluster and possible microwave paths. In Eastern Region, there is one high bandwidth utilization cluster and in this cluster, the connection between Eastern Region HQ and the 1st Avenue site is the most constrained segment. The other high bandwidth connection is between Eastern Region HQ and the Wandermere Maintenance Facility, but since this cluster is just under 20% utilization, it is not indicated on the map as a high utilization cluster.

While some of the remote facilities may be able to be fed by microwave (specifically Colville, Colfax and Davenport Maintenance facilities), it is unclear whether the Wandermere or the 1st Avenue site could be fed by microwave. While both appear to be directly along existing microwave paths, neither are at a terminus of the microwave shot. More work would have to be preformed to determine whether these sites are candidates for microwave connectivity back to Eastern Region HQ.

Figure 35 illustrates the North Central Region leased line segment, high utilization segment and possible microwave paths. In this region, the only high utilization segment is the Wenatchee – Euclid segment, which does not appear to be a candidate for a microwave shot. All other potential microwave paths to other facilities shown on this map are likely low priority as they are lower bandwidth connections. The microwave path between Wenatchee and Yakima was discussed previously.

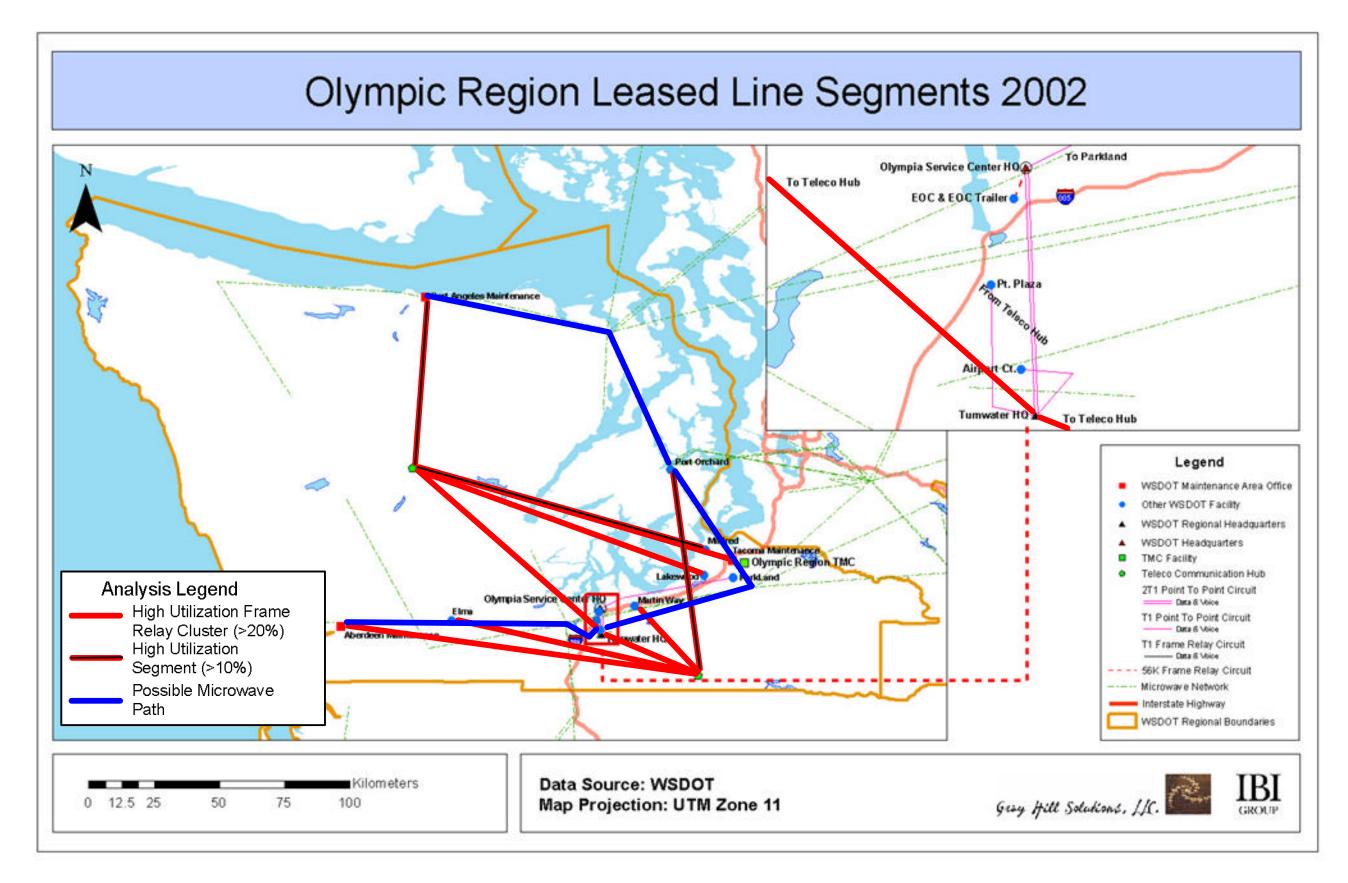


Figure 31: Olympic Region Analysis Map

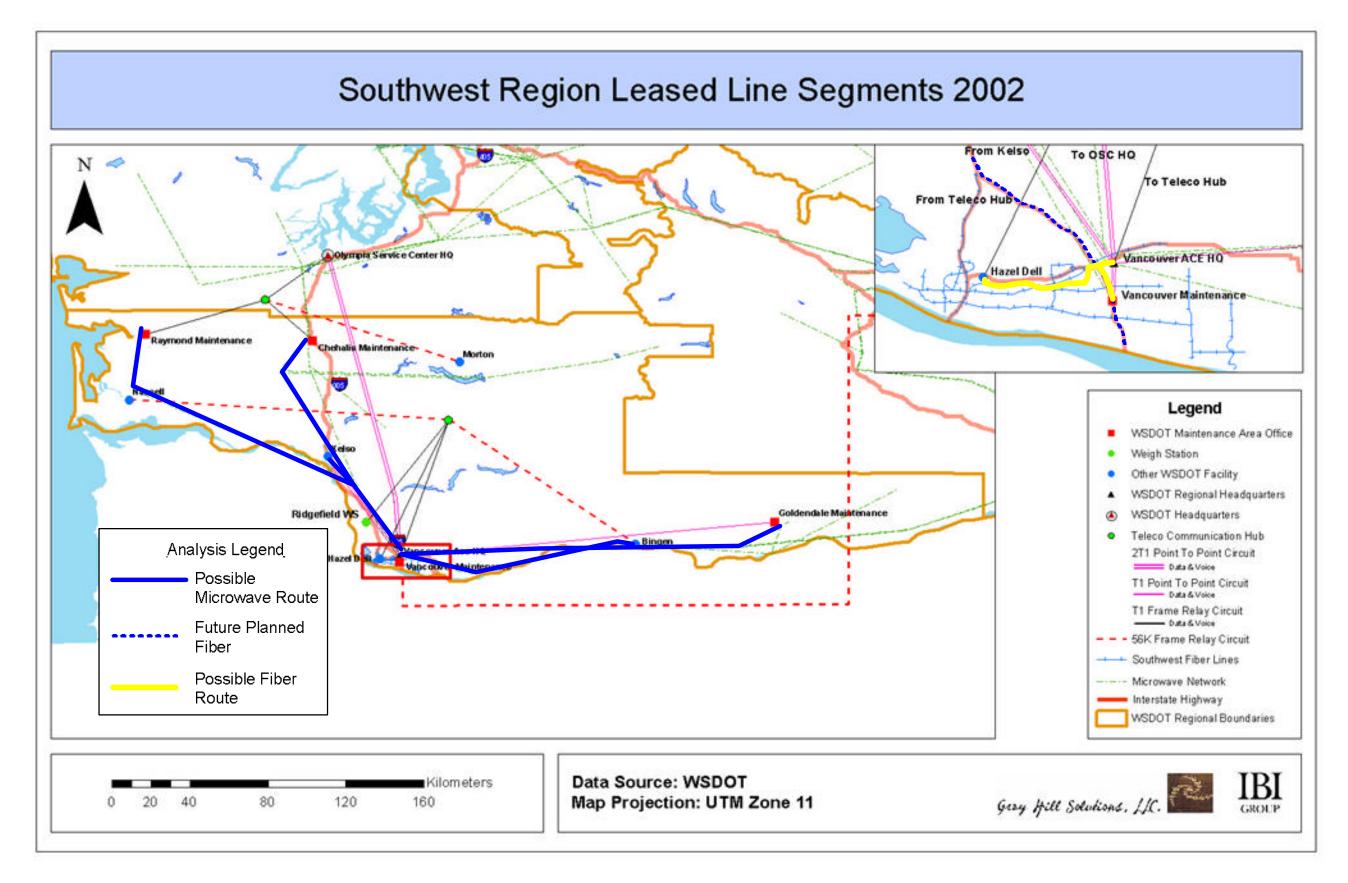


Figure 32: Southwest Region Analysis Map

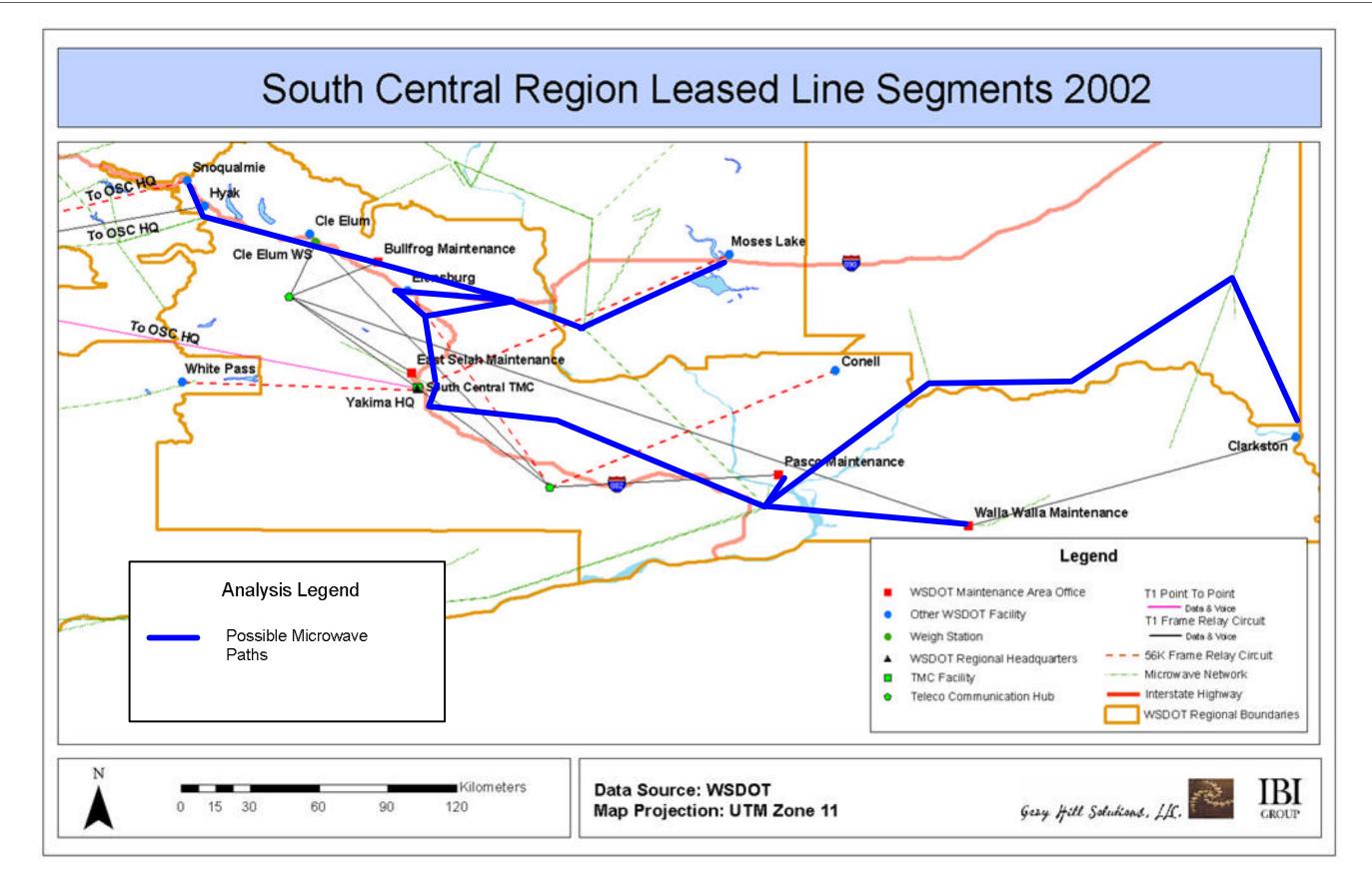


Figure 33: South Central Region Analysis Map

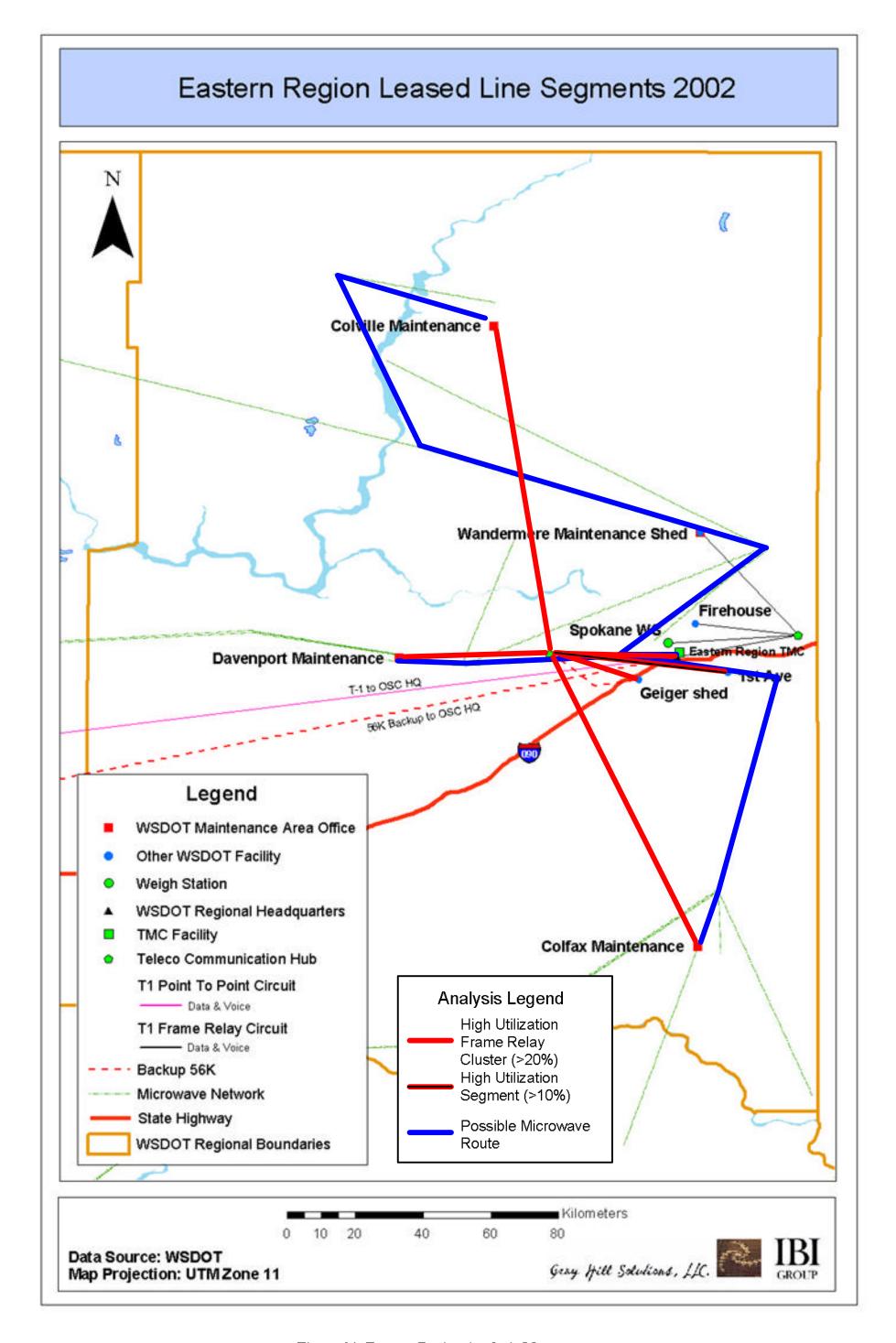


Figure 34: Eastern Region Analysis Map

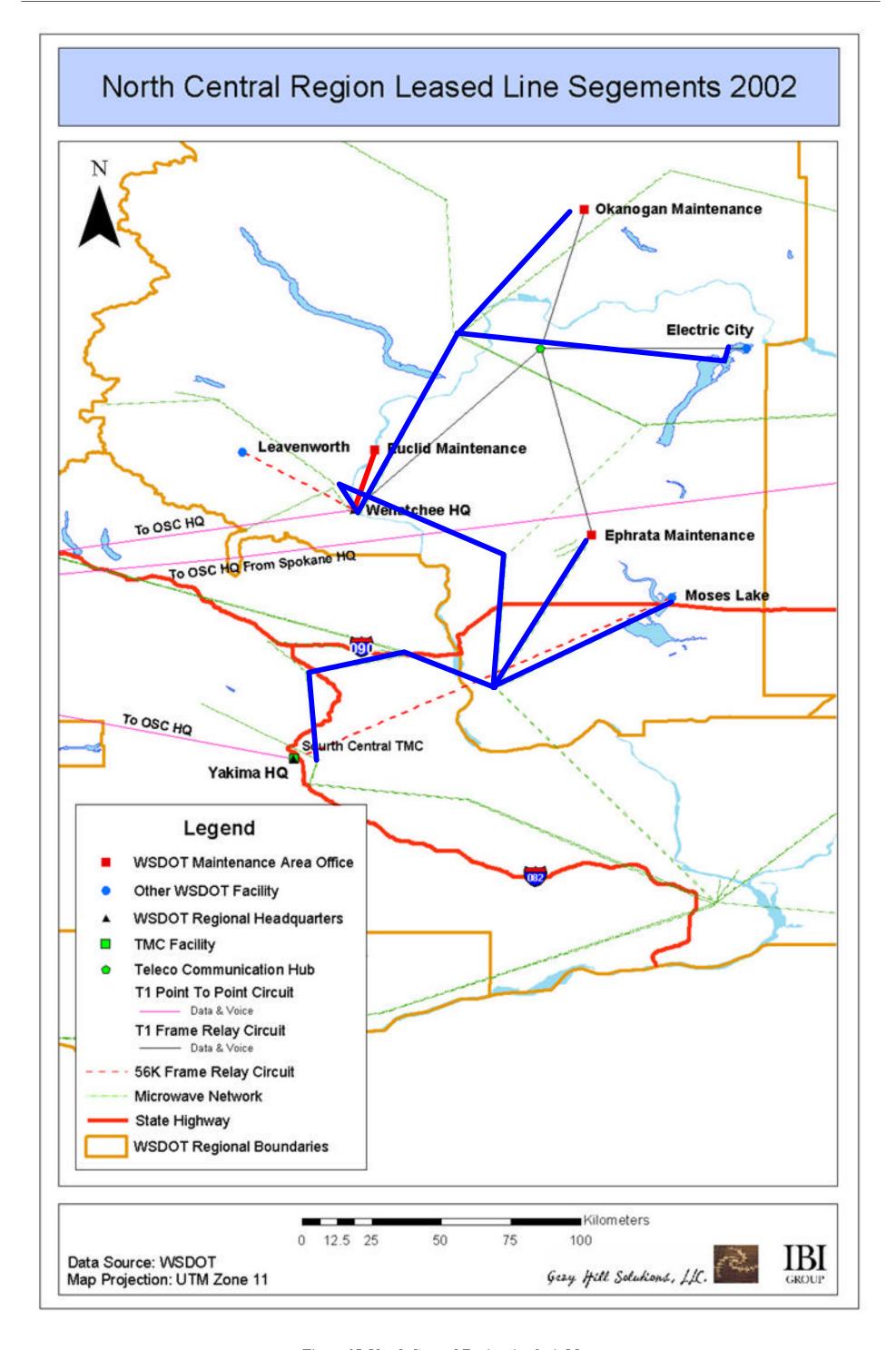


Figure 35: North Central Region Analysis Map

Figure 36 illustrates the Seattle – Everett Metro Area Analysis map. This map was specifically developed due to the density of sites in the Seattle metro area, especially when all of the WSF sites are included (WSF sites were not included in NW Region map.) The high utilization Frame Relay clusters identified in Figure 30 for the NW Region are not repeated in this map. Only the WSF high utilization cluster is included here.

As displayed on the map there appear to be no specific opportunities to utilize either microwave or fiber to connect to any of the WSF sites in the metro area, including the high utilization cluster.

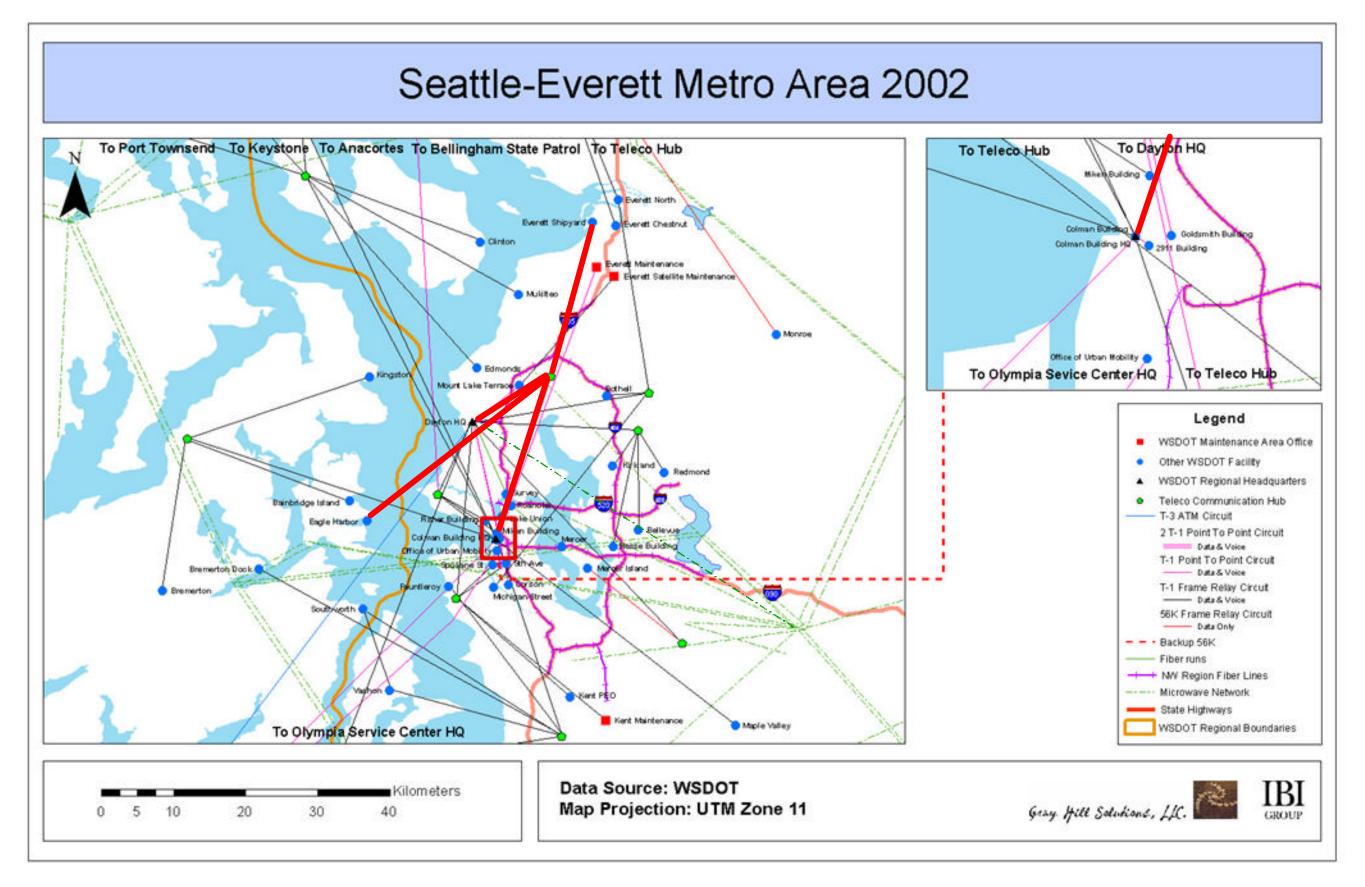


Figure 36: Seattle - Everett Metro Area Analysis Map

5.3 CENTER-TO-FIELD DATA AND VIDEO

Fiber optic cable has generally been installed as part of the Surveillance, Control and Driver Information (SCandDI) elements of freeway or HOV lane widening projects throughout the urban portions of the state. One of the key driving factors in determining when fiber is justified, is the density of devices that are existing or planned in a given section of roadway. Fiber optic cable is expensive to install and maintain, however, when a section of roadway has many devices the cost may be justified and the benefits three-fold:

- Reduced operating cost: Without the provision of state-owned communications infrastructure (such as fiber or wireless), each device requires a dedicated leased line or dial-up link. Higher bandwidth connections are required for video. Costs can become prohibitive when many devices are located in the same vicinity.
- **Quality of signal**: This is particularly important for CCTV cameras. When a low capacity leased line or dial-up option are only available, only snap shot or limited frame images can be received from the cameras.
- Polling rates of data devices: For low speed data devices, such as traffic sensors, RWIS, etc, fiber optic connections support much more frequent polling of the data.

Even when fiber can be justified due to density of devices, new construction can still be cost prohibitive. WSDOT has an informal policy in place, to "piggy-back" on to construction projects, such as lane widening, HOV lane construction, etc., to help reduce the incremental cost of construction of the communications infrastructure and ITS field equipment.

In an effort to determine rules of thumb for priority corridors for fiber optic construction, the data on ITS device locations (which was collected during the Light Lanes project) was analyzed and a series of maps were developed. These maps indicate "ITS Device Densities." The data collected in Light Lanes included both existing and planned ITS devices along the key WSDOT corridors.

The following rules were applied in developing these maps:

- 1. Roadways were analyzed in 5 mile segments
- 2. Device density was calculated as number of devices per mile, with the following parameters:
 - .1 to .4 Devices per Mile = Low Density
 - .4 to .7 Devices per Mile = Medium Density
 - .7 to 1.9 Devices per Mile = High Density
 - Greater than 1.9 Devices per Mile = Very High Density
- 3. Only High and Very High Densities were identified on the maps

Also included on the maps are the various WSDOT and WSP office locations. Another factor in determining where fiber is justified may be density of these offices. This fiber may be used as a backbone to connect various offices for both ITS and Enterprise data as discussed previously.

The analysis of these ITS device densities considered the following factors:

- Segments of "Very High" density of devices are a high priority for fiber construction
- Segments of "High" density of devices, with a corresponding high density of offices are also a high priority for fiber construction.
- Segments of "High" density of devices, with few or no offices are medium priority for fiber construction.
- Segments of "Medium" or "Low" density of devices (and therefore not indicated on map) are low priority for fiber construction.

Figure 37 presents the Northwest Region ITS Device Density Map. The Very High density segments generally correspond with the existing SCandDI Fiber Ring around Lake Washington, including crossing both floating bridges. The only exceptions are Snoqualmie Pass (where WSDOT has a dedicated microwave network connecting devices) and south from the existing fiber ring to Tacoma (this segment carries on into the following map.

The density of WSDOT offices is generally in the downtown Seattle area. WSDOT already owns fiber along the DOT right-of-way through this area, so no new construction is recommended. (WSDOT may want to consider working with City of Seattle to use their fiber network in the city as "last mile" connections between their existing fiber ring and their offices.)

An argument could be made that extending the fiber network north to the Everett North facility might be justified, but further cost/benefit analysis would be required.

Figure 38 is the ITS Device Density Map for the Olympic Region. As discussed above, the segment of Very High density of devices continues south from the existing fiber ring in the Northwest Region, down to Tacoma. Therefore, this corridor may be considered high priority for fiber construction. This schematic only includes the regional offices, such as Maintenance area offices, Project Engineering offices and maintenance sheds. However, there are a number of other WSDOT facilities located in the Olympia region, including numerous headquarters facilities. Therefore, a specific map was developed focusing on the Olympia to Tacoma metro area.

Figure 39 is the ITS Device Density map for the Olympia – Tacoma Metro Area. This map illustrates two features:

- The existing fiber network in Tacoma (built by the Tacoma Fire Dept., but WSDOT has ownership of half of the fiber as discussed in another section)
- The high density of offices in the Olympia area.

The relevance of the existing fiber network in Tacoma is that the High Density segment terminates near the crossing of this existing fiber. Therefore, if fiber where built to this point, it would ensure connectivity between the Northwest SCandDI fiber network and the Tacoma fiber network

The relevance of the high density of offices in Olympia goes back to the recommended rule of thumb, i.e., high density of devices and high density of offices indicates high priority fiber segment. Again, WSDOT may want to work with the City of Olympia to use their growing city fiber network as "last mile" connections to connect to these offices.

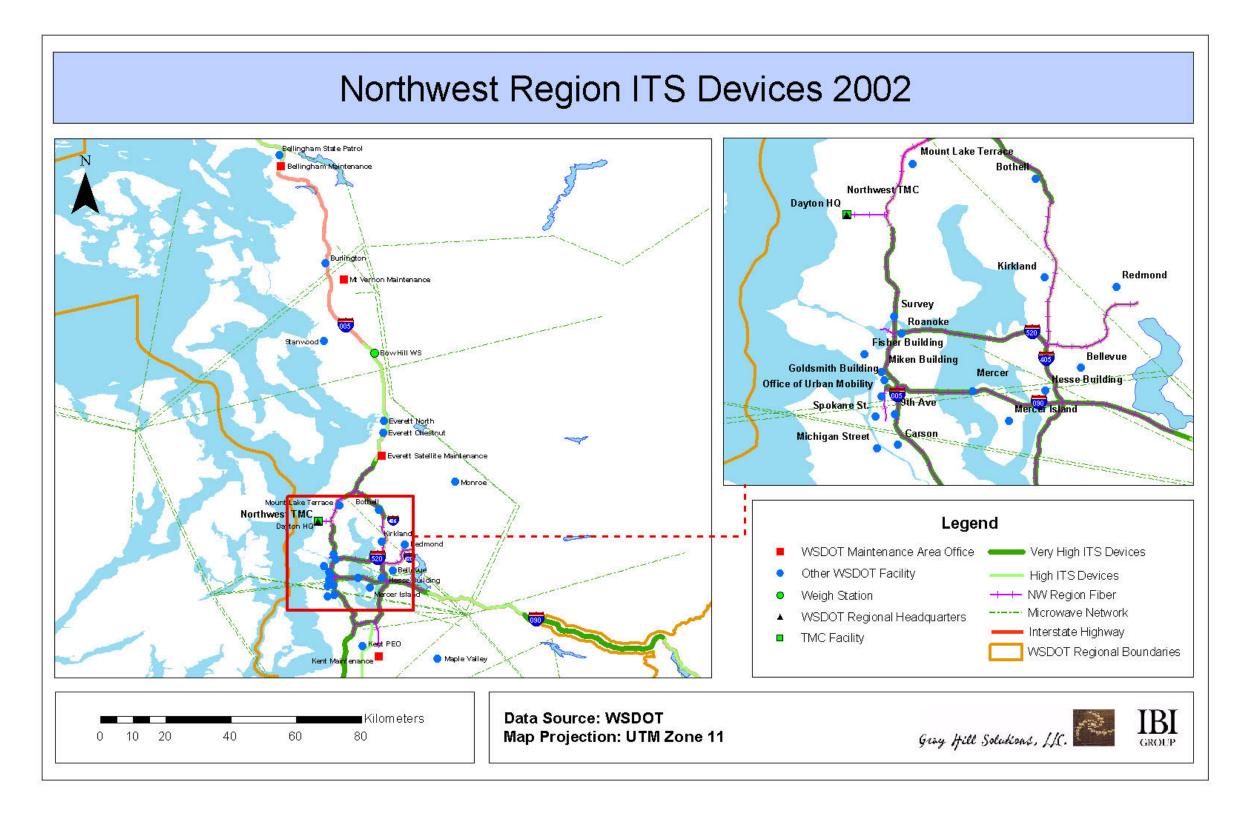


Figure 37: ITS Device Density Analysis Map – Northwest Region

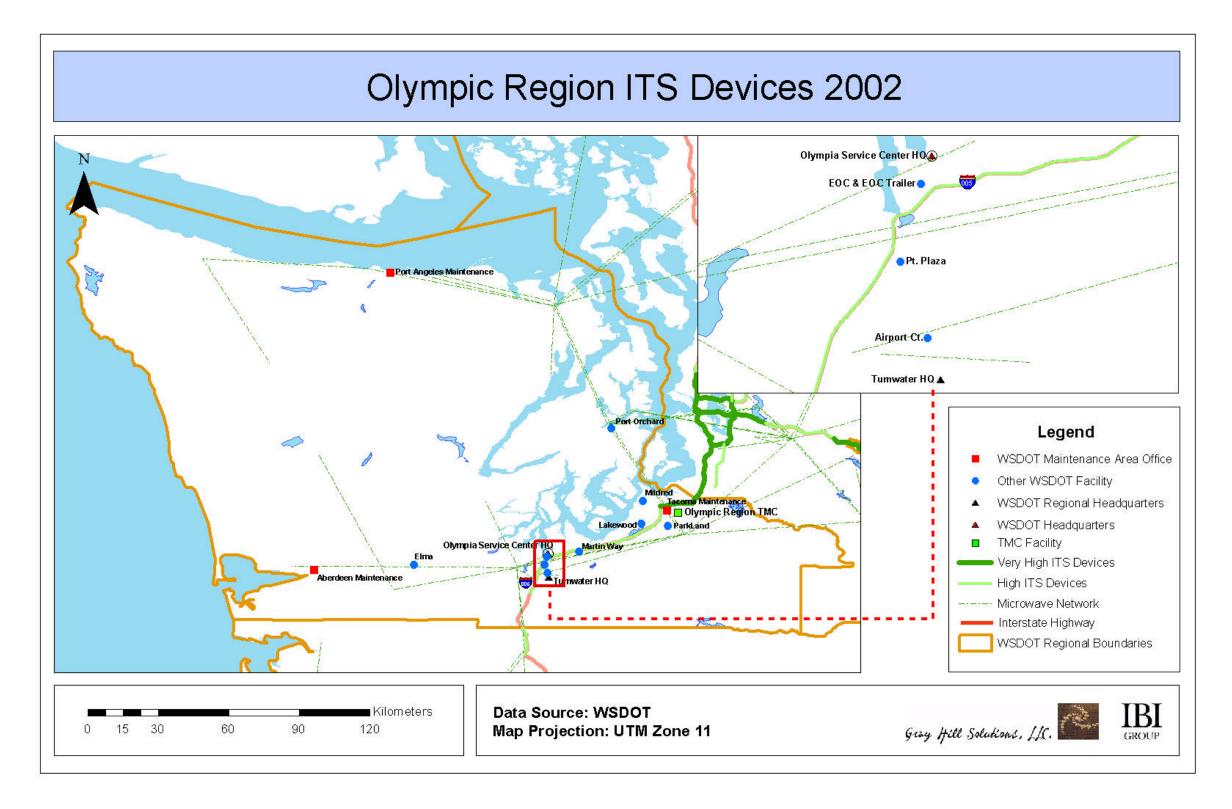


Figure 38: ITS Device Density Analysis Map – Olympic Region

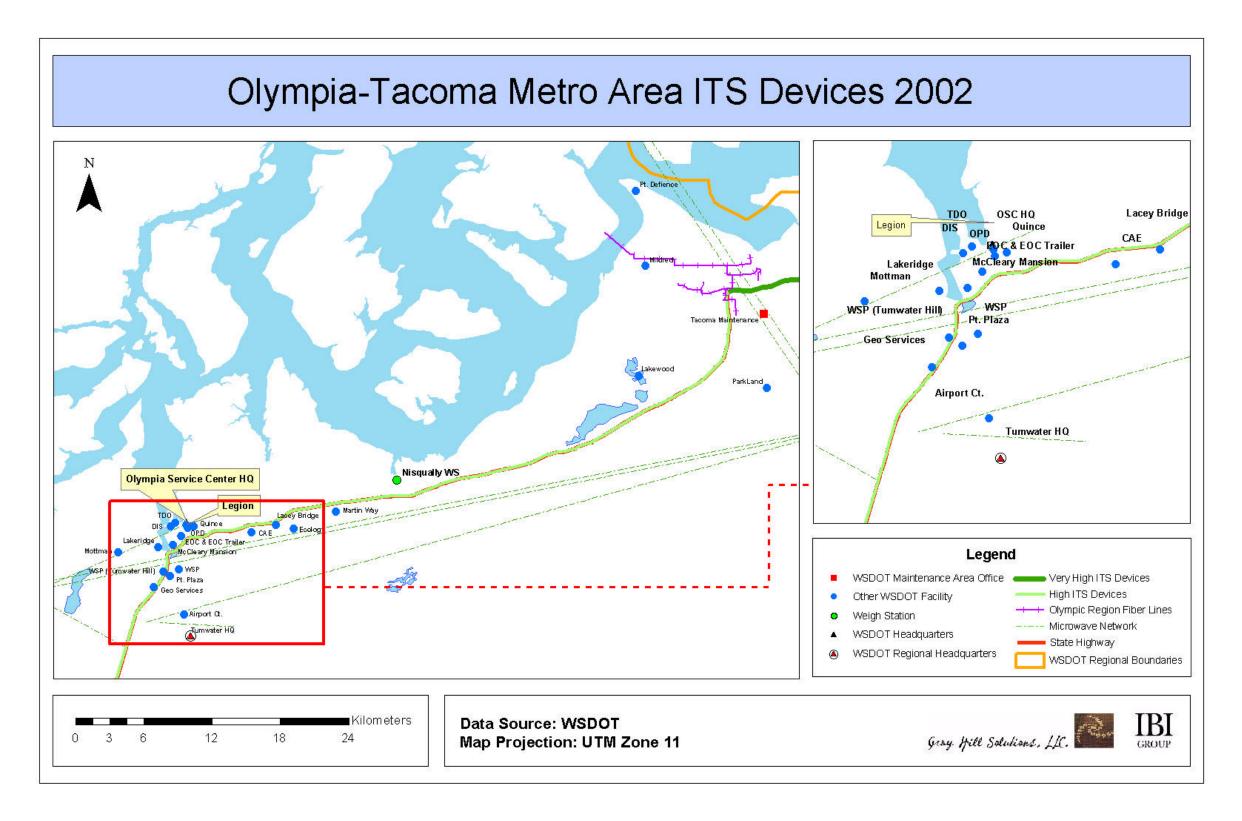


Figure 39: ITS Device Density Analysis Map – Olympia – Tacoma Metro Area

Figure 40 is the ITS Device Density map for Southwest Region. As illustrated on this map, the Very High density of devices form a triangle between I-5, I-205 and SR 14, extending a short distance up I-5 beyond the I-205 interchange. This triangle is therefore a potential high priority for fiber construction. The High-density segment from Ridgefield past Kelso also does not have a high density of WSDOT offices and is therefore a potential medium priority fiber construction segment, as is the small segment near Chehalis.

Figure 41 is the ITS Device Density map for the Eastern Region. As illustrated on this map, there is a Very High density of devices from west Spokane east to the Idaho border, therefore this may be considered a high priority for fiber construction. As illustrated on this map, there is a small segment of existing fiber in this region, some of which is included on this high priority corridor. The Geiger shed further to the west of Spokane is a low bandwidth site, and does not likely justify extending the fiber construction further west.

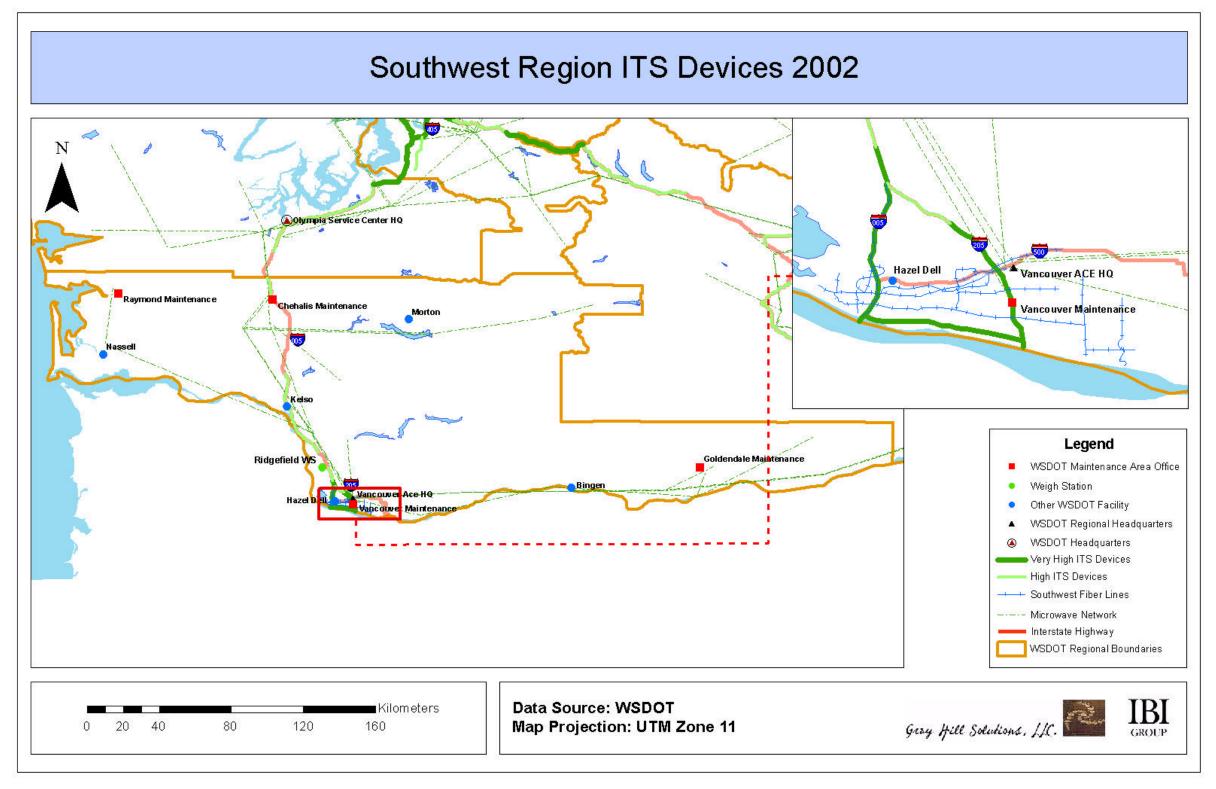


Figure 40: ITS Device Density Analysis Map – Southwest Region

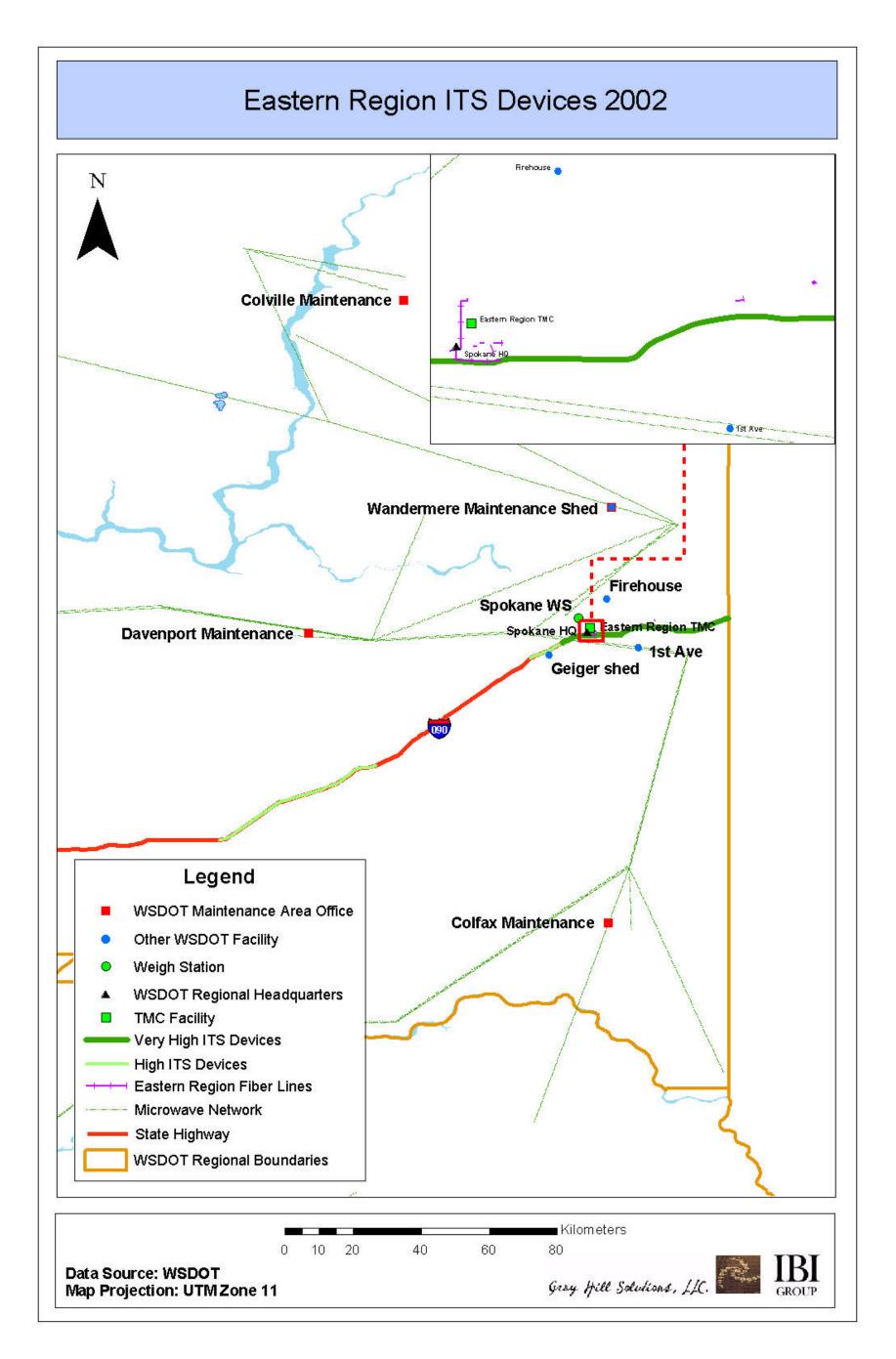


Figure 41: ITS Device Density Analysis Map – Eastern Region